

## FIXED-INTERVAL PERFORMANCE: THE DYNAMICS OF BEHAVIOR AND THE INTERVAL LENGTH

J. H. WEARDEN AND C. F. LOWE

UNIVERSITY OF MANCHESTER AND  
UNIVERSITY COLLEGE OF NORTH WALES, BANGOR

Postreinforcement pauses from successive intervals under various fixed-interval schedules (ranging from 15 seconds to 480 seconds in length) were subjected to lag-1 autocorrelation analysis. Results from both rats and pigeons suggested that there was a consistent tendency for pause values in successive intervals to be weakly positively related. This tendency did not appear to change systematically with interval length and was exhibited both when the reinforcer magnitude was constant and when it was variable at different interval values. The findings do not support suggestions that the dynamic properties of performance under fixed-interval schedules vary systematically with interval length, and are in the opposite direction from some previous findings suggesting that measures of behavior (such as postreinforcement pause length or number of responses) in successive intervals are inversely related.

*Key words:* fixed-interval schedules, postreinforcement pauses, dynamic effects, autocorrelations, lever press, key peck, rats, pigeons

It has long been known that performance in individual intervals in sessions of fixed-interval (FI) reinforcement is variable from interval to interval (Dews, 1970; Ferster & Skinner, 1957), although there is some dispute about how the variation should be characterized. The most common suggestion (deriving initially from Ferster and Skinner, 1957) is that measures of performance in successive intervals should be inversely related—for example, with intervals containing many responses succeeded by intervals containing few responses and with intervals containing long postreinforcement pauses followed by intervals containing short pauses (Shull, 1971). One way of assessing the strength of such tendencies is to employ the lag-1 autocorrelation (Weiss, Laties, Siegel, & Goldstein, 1966), a statistic that varies in value from  $-1.0$  (if successive measures are inversely related), through  $0$  (if successive measures are unrelated), to  $1.0$  (if successive measures are strongly positively related).

Shull (1971) investigated postreinforcement pause autocorrelations in data from two pi-

geons run under FI schedules of 30, 60, and 300 sec and found these to be negative only at the highest value, but inconsistent or positive at lower values. Wearden (1979) presented autocorrelations derived from measures of postreinforcement pauses and number of responses per interval produced by rats under FI schedules of 60, 120, and 180 sec and found them to be of generally small magnitude and neither consistently positive or negative. More recently, Lowe and Wearden (1981) provided some evidence that postreinforcement pause autocorrelations from rats and pigeons tended to be of small positive value under a variety of FI schedules, a result consistent with some aspects of their model of more complex pause periodicities.

Gentry and Marr (1982) have recently suggested that the discrepancy between the results produced by earlier workers is due to an effect of fixed-interval value, with measures of behavior tending to exhibit little evidence of the kind of dynamic effects analyzable by lag-1 autocorrelations at low FI values, but showing clear effects at higher values. The present article is intended to contribute some data to this debate. Postreinforcement pauses in individual intervals from FI schedules ranging in value from 15 sec to 480 sec—a higher value than those employed either by Gentry and Marr (1982) or Shull (1971)—were obtained

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A revised version of this article was prepared while the author was visiting the University of Utah. The author thanks Charles P. Shimp and his colleagues for their help and hospitality. Reprints may be obtained from J. H. Wearden, Department of Psychology, The University of Manchester, Manchester M13 9PL, United Kingdom.

from rats and pigeons and subjected to lag-1 autocorrelation analysis.

### METHOD

The procedure used to collect the data analyzed in the present article has been fully reported by Lowe, Harzem, and Spencer (1979), so only a brief account will be given here.

Four hooded rats were exposed (in Lehigh Valley 143-25 chambers) to FI values ranging from 15 to 480 sec, and values of 15, 120, and 480 sec were repeated. In all cases the operant response was lever pressing and a 45-mg food pellet was used as the reinforcer. The order of exposure to the FI schedules was 60, 30, 120, 480, 15, 240, 120, 480, and 15 sec. Exposure to a particular schedule condition continued until a stability criterion was met (see Lowe et al., 1979, for details), and duration of exposure to different conditions ranged from 8 to 24 sessions.

Four mixed-breed pigeons were exposed (in Lehigh Valley 141-16 chambers) to FI values ranging from 15 to 480 sec. The measured response was key pecking and two different reinforcer conditions were employed. In one (constant reinforcer—C) the reinforcer was a constant 3-sec access to grain; in the other (proportional reinforcer—P) the reinforcer was access to grain for a time equal to  $\frac{1}{10}$ th the interval value. All birds were exposed to both types of reinforcer condition. For Birds 1 SG and 2 SG the order of presentation of the FI schedules was 15 (P), 480 (P), 120 (P), 60 (P), 60 (C), 480 (C), 15 (C), 120 (C), 240 (C), and 240 (P); for Birds 3 SG and 15 C the order was 120 (C), 15 (C), 480 (C), 60 (C), 60 (P), 120 (P), 480 (P), 15 (P), 240 (P), and 240 (C). Exposure to a particular schedule condition continued until a stability criterion was met (see above), and duration of exposure to different conditions ranged from 8 to 56 sessions.

### RESULTS

Postreinforcement pauses from successive intervals during the last three sessions of each schedule condition were subjected to autocorrelation analysis. The resulting values are shown in Figure 1, with the upper panels showing data from the rat subjects, the lower panels results produced by pigeons.

Considering the results from rats first, Fig-

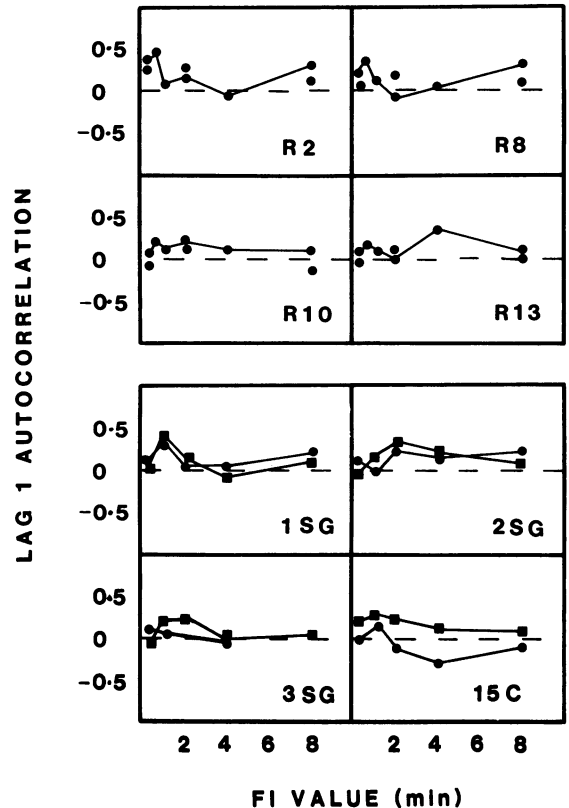


Fig. 1. Autocorrelation values from rat subjects (upper four panels) and from pigeons (lower four panels). For the rats, unconnected points indicates values from replicated FI conditions. In the panels showing results from pigeons, filled circles indicate data from the constant reinforcer condition, filled squares data from the proportional-reinforcer condition.

ure 1 shows that the overwhelming majority of pause autocorrelations were positive (31 out of 36 values). They were also generally of small magnitude and exhibited no obvious tendency to alter in value or sign with interval length. Only one subject (R10) produced more than one negative autocorrelation, and even this subject did not exhibit any tendency for autocorrelation value to vary systematically with interval length.

Data from pigeons were collected under two experimental conditions, either with a constant (3-sec) reinforcer or with a reinforcer duration equal to one-tenth the interval value. Considering data from the constant-reinforcer condition first, Figure 1 shows that the majority of autocorrelation values were positive. Two data points (from FI 120 and FI 480-sec) were unavailable for analysis in Bird 3 SG. Of the remaining points, 14 out of 18 were posi-

tive, and three of the negative points came from Bird 15 C. This bird tended to exhibit negative autocorrelations at the longer FI values employed, whereas for the other subjects the values were generally small and positive at all interval values. Autocorrelation values produced under the proportional reinforcer conditions were similar, being generally positive (16 out of 20 cases), of small magnitude, and exhibiting no obvious change with interval value. Only one bird (3 SG) exhibited more than one negative autocorrelation.

## DISCUSSION

The present results suggest that, at least for postreinforcement pause measures, any influences from one interval under FI to the next tend to be weakly positive. No evidence was found to support Gentry and Marr's (1982) suggestion that negative autocorrelations occur on long FI schedules, as the longest value employed in the present study (FI 8-min) was longer than any employed by either Shull (1971) or Gentry and Marr (1982). It should be noted, however, that the present study employed pause measures, whereas Gentry and Marr (1982) used numbers of responses per interval. These two measures of FI performance may have different dynamics, although available evidence (from Wearden, 1979) suggests that when collected in the same intervals they do not, at least at FI values up to 3 min.

The discrepancy between the results presented above and those of Gentry and Marr (1982) might possibly be due to procedural differences between their study and ours. Subject species and apparatus differed between the two studies and Gentry and Marr (1982) employed a smaller reinforcer magnitude (2.5-sec access) than that employed by Lowe et al. (1979). On the other hand, the fact that generally positive autocorrelations are obtained in the proportional-reinforcer condition above (in which access to grain is usually longer than 2.5 sec) tends to argue against a role for reinforcer magnitude in the determinations of sign of autocorrelation.

Other differences between Gentry and Marr's study and our own concern the subjects' training history. Their subjects had received only a single FI-schedule condition (FI 5-min) and had previous histories of second-order schedules. Both the rats and pigeons from

which results are derived above had previous histories of FI performance. It does not appear, however, that there was any obvious tendency for positive, rather than negative, autocorrelations to develop throughout exposure to a series of different FI schedules. For the rats employed above, autocorrelations in the first schedule condition reported (FI 60-sec) did not seem to differ systematically from those collected in the last (the second exposure to FI 15-sec). Two of the pigeon subjects (2 SG and 15 C) did exhibit negative autocorrelations in the first FI schedule reported above and positive ones on the last, but 1 SG exhibited the opposite trend. The first schedule condition for 3 SG was unavailable for analysis. These comparisons are complicated by the fact that all subjects had prior histories of FI schedules. The rats employed by Wearden (1979), which were naive previous to the reported FI training, did not show any obvious tendency for autocorrelations to become increasingly positive throughout the series of FI schedule conditions used. Overall, therefore, the evidence for changes in types of dynamics throughout a series of FI values is not strong, although the routine use of experienced subjects makes evidence on this point difficult to obtain from published work.

The contrast between the present findings (in which autocorrelation measures were most commonly positive) and those of Gentry and Marr (1982), where results from pigeons under FI 5-min were consistently and replicably negative, appears striking. Furthermore, both the above results and those of Gentry and Marr contrast with the findings of Wearden (1979) that pause and response-number measures from rats under FI values of 1, 2, and 3 min exhibited very small autocorrelations of inconsistent sign. It should be noted, however, that even when autocorrelations are consistently positive or negative, absolute values tend to be low, indicating that little of the variance of behavior in one interval is accounted for by behavior in the previous interval. It is possible that the dynamic effects measured by autocorrelation statistics may be a secondary consequence of a type of dynamic output process that imposes looser constraints on behavior than that performance measures in successive intervals bear some simple numerical relation to one another. There is previous evidence that the autocorrelation statistic, which is sen-

sitive to such simple sequential relations, may not reliably capture all the interesting aspects of schedule dynamics under FI schedules. For example, Wearden (1979) found that autocorrelation measures revealed no consistent trends in data from rats under FI schedules, but that another type of analysis revealed that the direction of change in output between pairs of intervals (e.g., whether response number increased or decreased between intervals  $n$  and  $n + 1$ ) varied much more than would be expected by chance. Reanalysis of previous results from Dews (1970) and Shull (1971) also revealed similar effects in their data (see also Lowe and Wearden, 1981, for another replication of this type of dynamic effect).

It is possible that the development of a model of such dynamic processes would reveal that the inconsistencies between the results of different studies described above could be described as small parametric variations in the basic dynamic output process. Until such a model is developed, however, discrepancies in the types of output dynamics found in different studies of FI schedules, each of which appears methodologically sound and each of which produces internally consistent results, may continue to resist simple explanation.

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Received May 17, 1982

Final acceptance September 28, 1982